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**Ungchusri et al.**

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(54) **MANIFOLD ASSEMBLY WITH MULTIPLE ARTICULATING ARM ASSEMBLIES**

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**Related U.S. Application Data**

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(51) **Int. Cl.**

| | |
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| ***E21B 43/26*** | (2006.01) |
| ***F16L 41/18*** | (2006.01) |
| ***F17D 1/08*** | (2006.01) |

(52) **U.S. Cl.**
CPC ................. ***F16L 41/18*** (2013.01); ***E21B 43/26*** (2013.01); ***F17D 1/08*** (2013.01); *Y10T 137/8807* (2015.04)

(58) **Field of Classification Search**
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USPC ........................................................ 137/615
See application file for complete search history.

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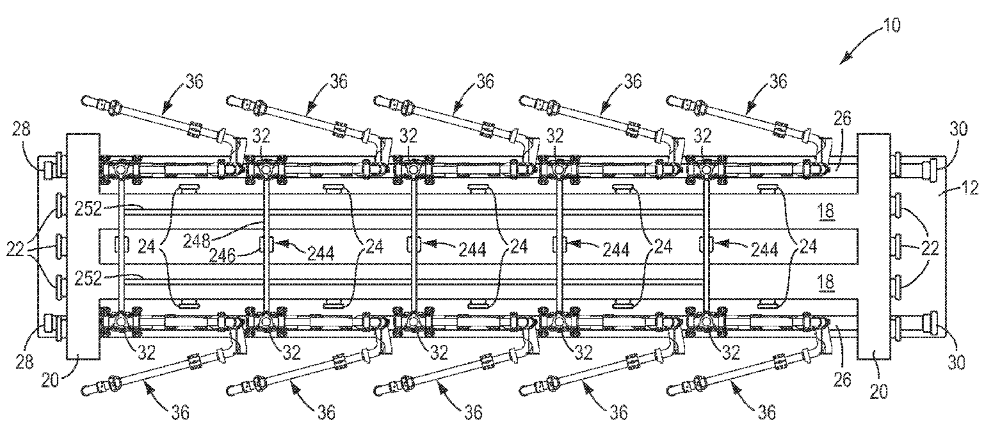
(57) **ABSTRACT**

A manifold assembly for connecting a plurality of pumping units to a wellhead includes at least one main line which is connectable to the wellhead and includes a plurality of discharge connectors, and a plurality of articulating arm assemblies which are each connected to a corresponding discharge connector. Each arm assembly comprises a connector member which includes at least an inlet port, an outlet port and a third port that is located generally opposite the outlet port and is closed by a removable plug member, an articulating conduit assembly which comprises a first end that is connected to the inlet port and a second end that is connectable to a corresponding one of the plurality of pumping units, and a riser swivel which is connected between the outlet port and the discharge connector. In use of the manifold assembly, each arm assembly is connected to a corresponding pumping unit and the main line is connected to the wellhead to thereby connect the pumping units to the wellhead.

**36 Claims, 14 Drawing Sheets**



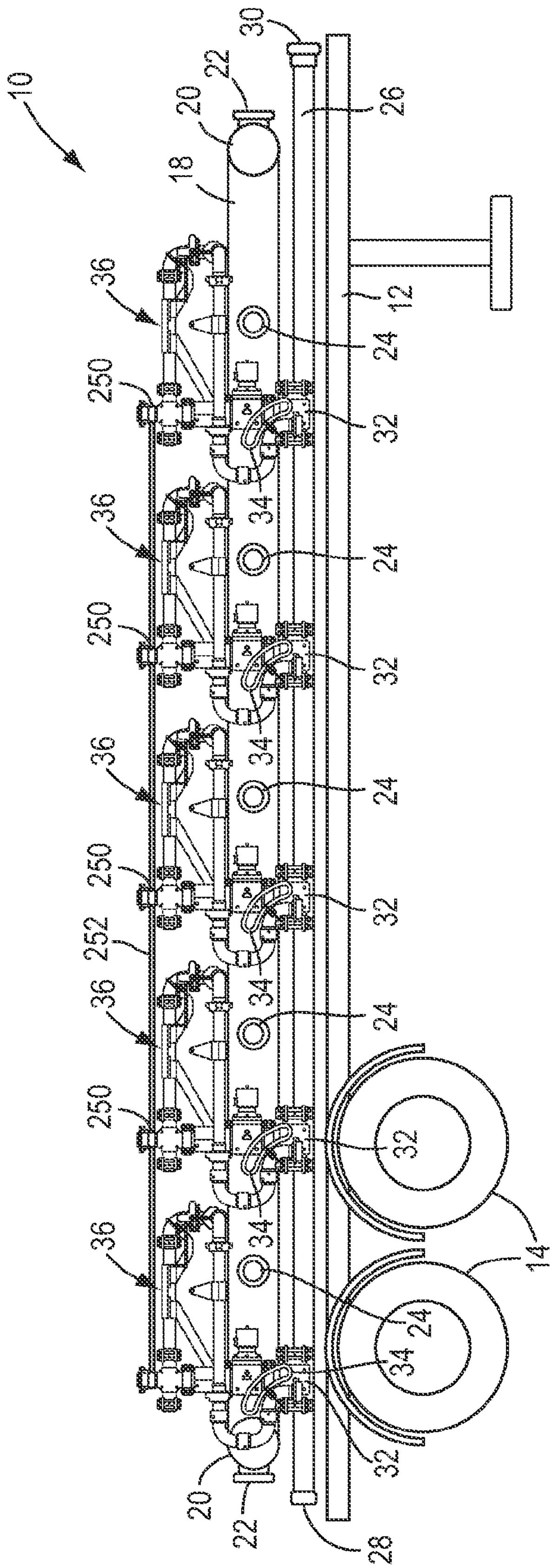



FIG. 1A

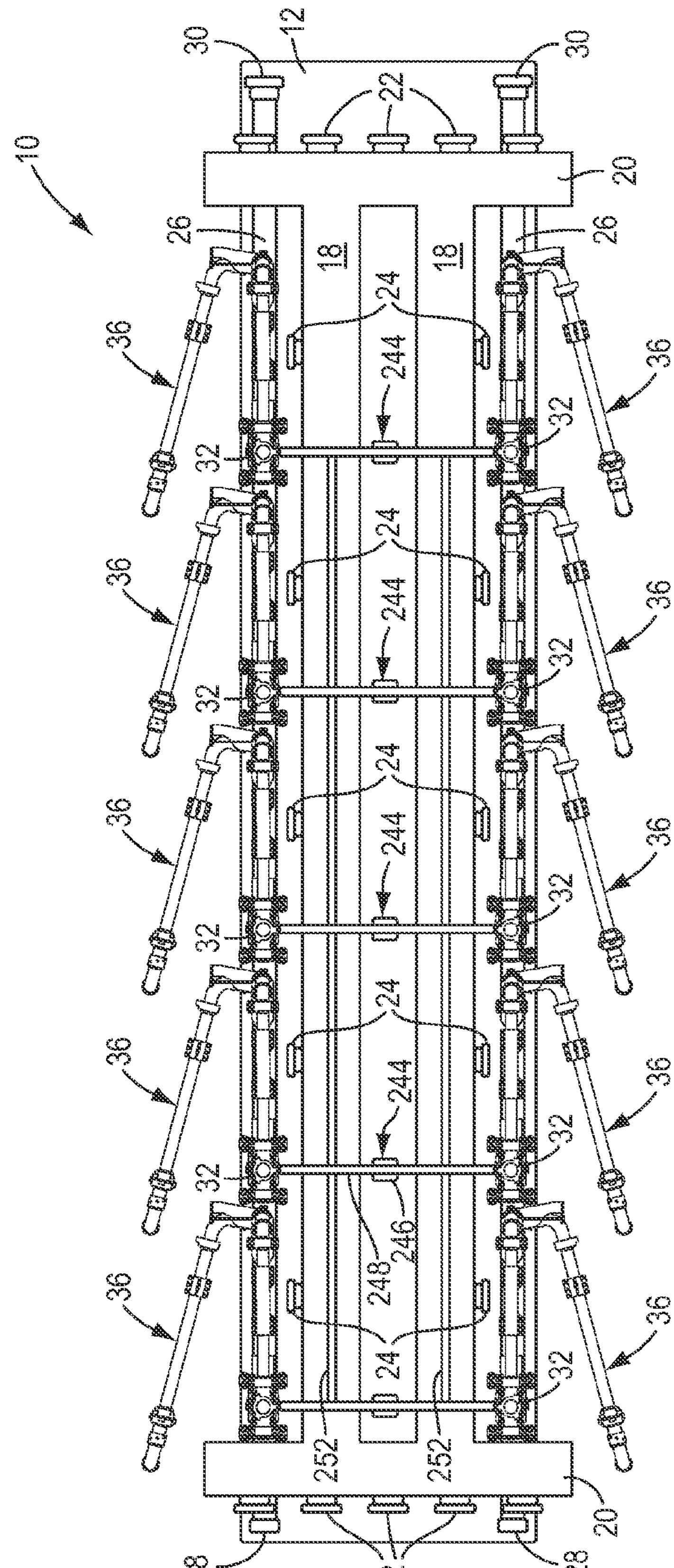
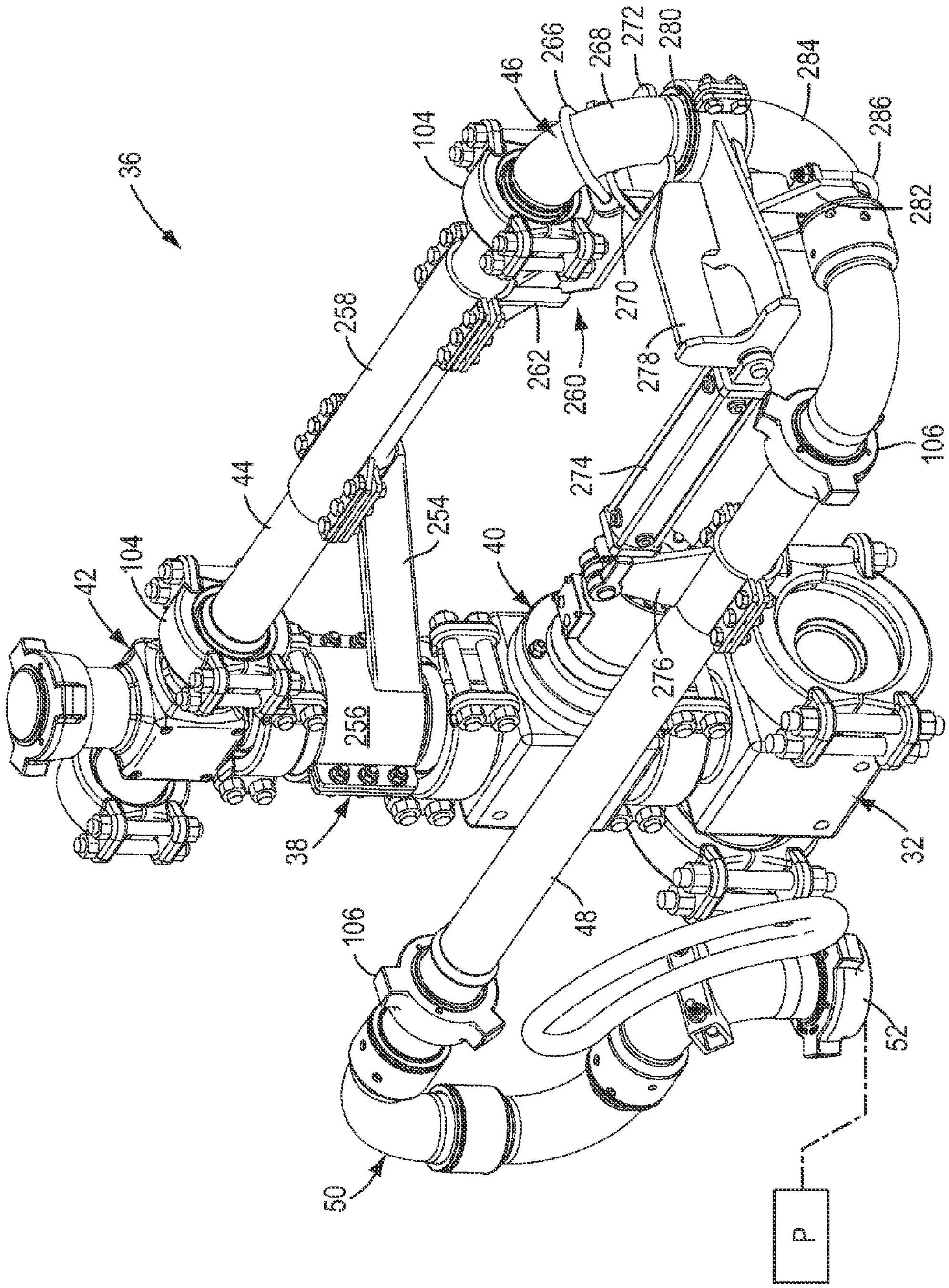



FIG. 1B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46
266
268
272
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284
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282
104
258
262
260
270
278
44
42
104
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274
106
276
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38
32
48
106
52
50
P

FIG. 2

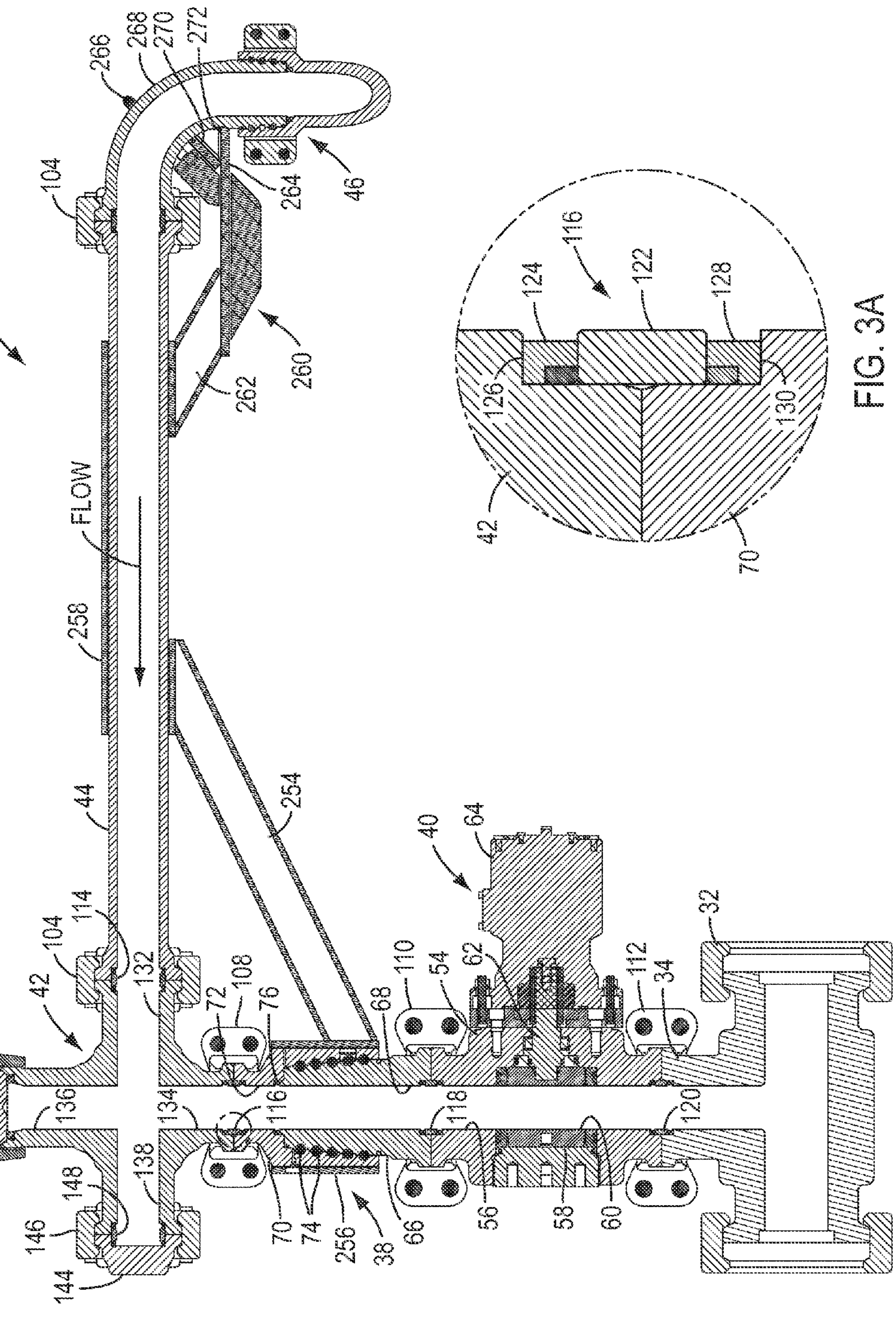

36
FLOW
44
258
254
262
260
264
46
266
268
270
272
104
114
132
42
142
140
136
134
138
148
146
144
108
72
76
116
70
74
256
38
66
68
110
54
118
56
40
64
62
58
60
112
34
120
32
124
122
128
126
130
42
70

FIG. 3

FIG. 3A

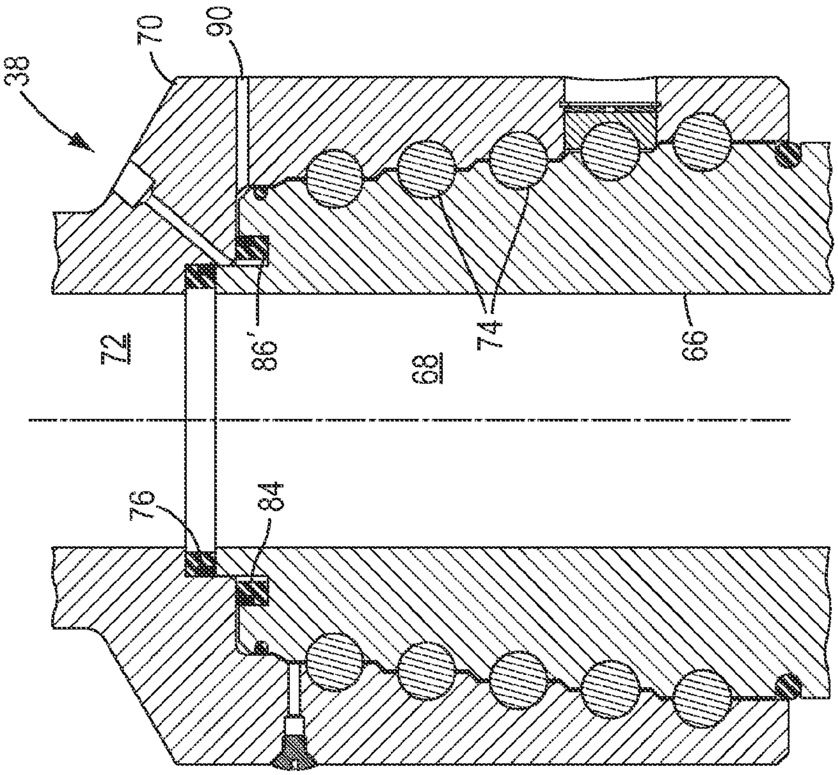
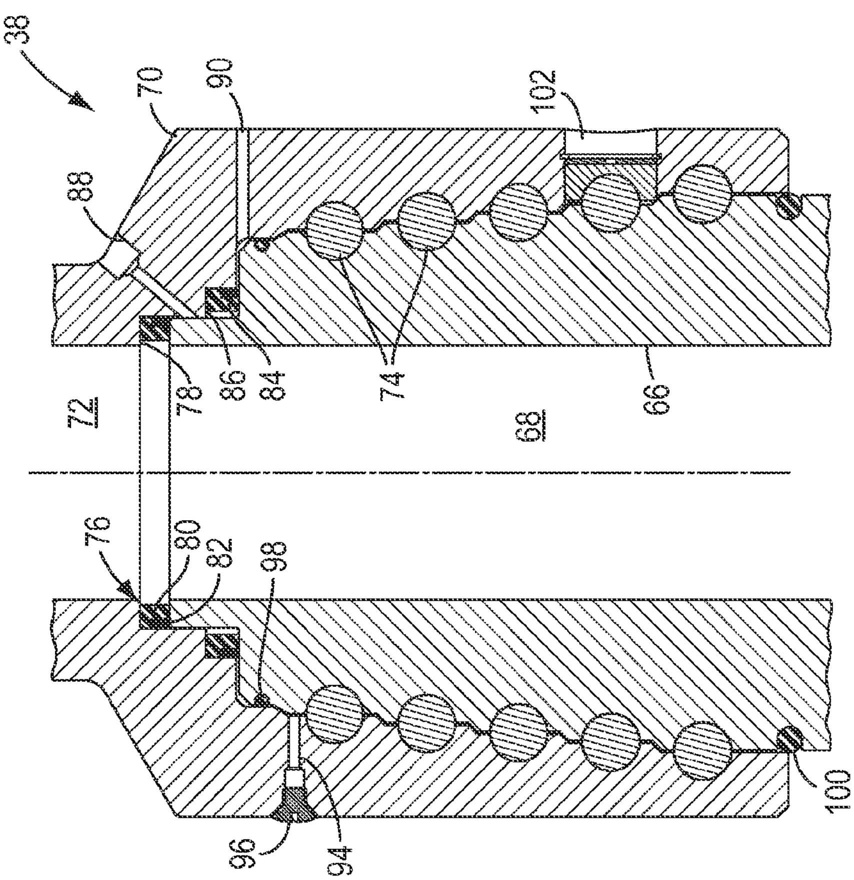

38
70
90
72
86'
68
74
66
76
84

FIG. 5


38
70
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74
66
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76
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82
98
96
94
100

FIG. 4

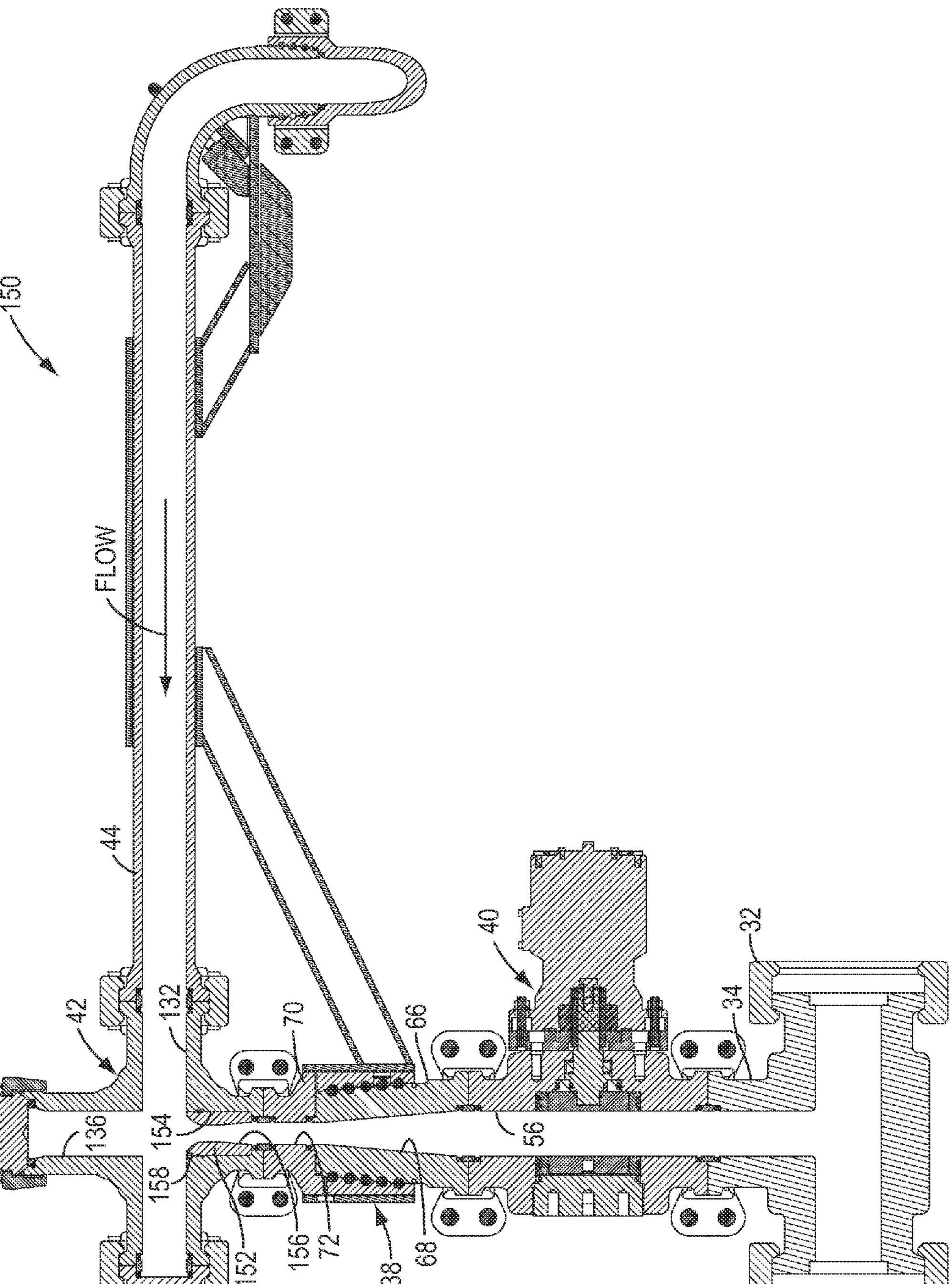
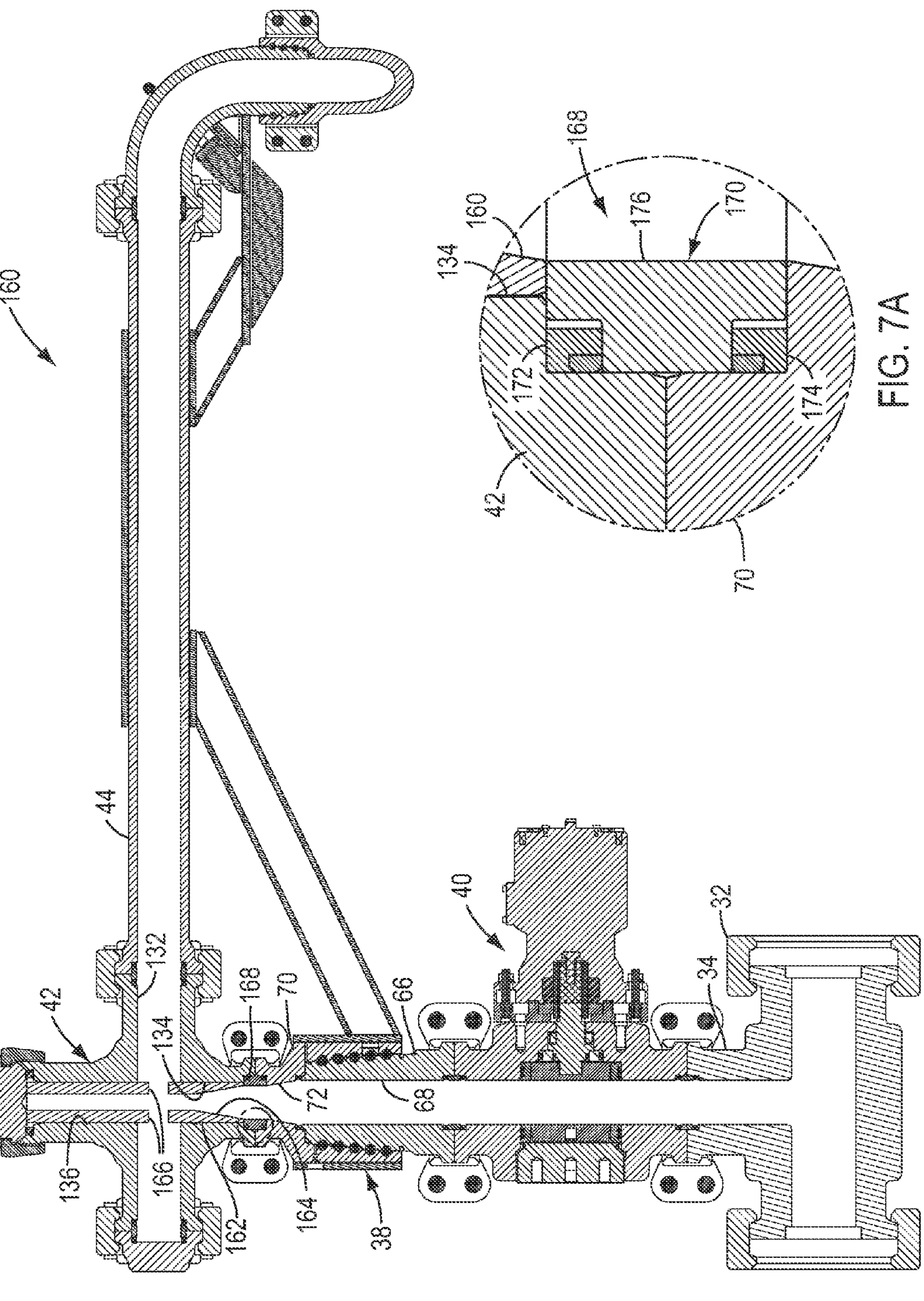

150
FLOW
44
42
140
136
132
154
158
152
156
72
70
38
68
66
56
40
34
32

FIG. 6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44
42
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132
134
136
166
162
168
70
72
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66
68
38
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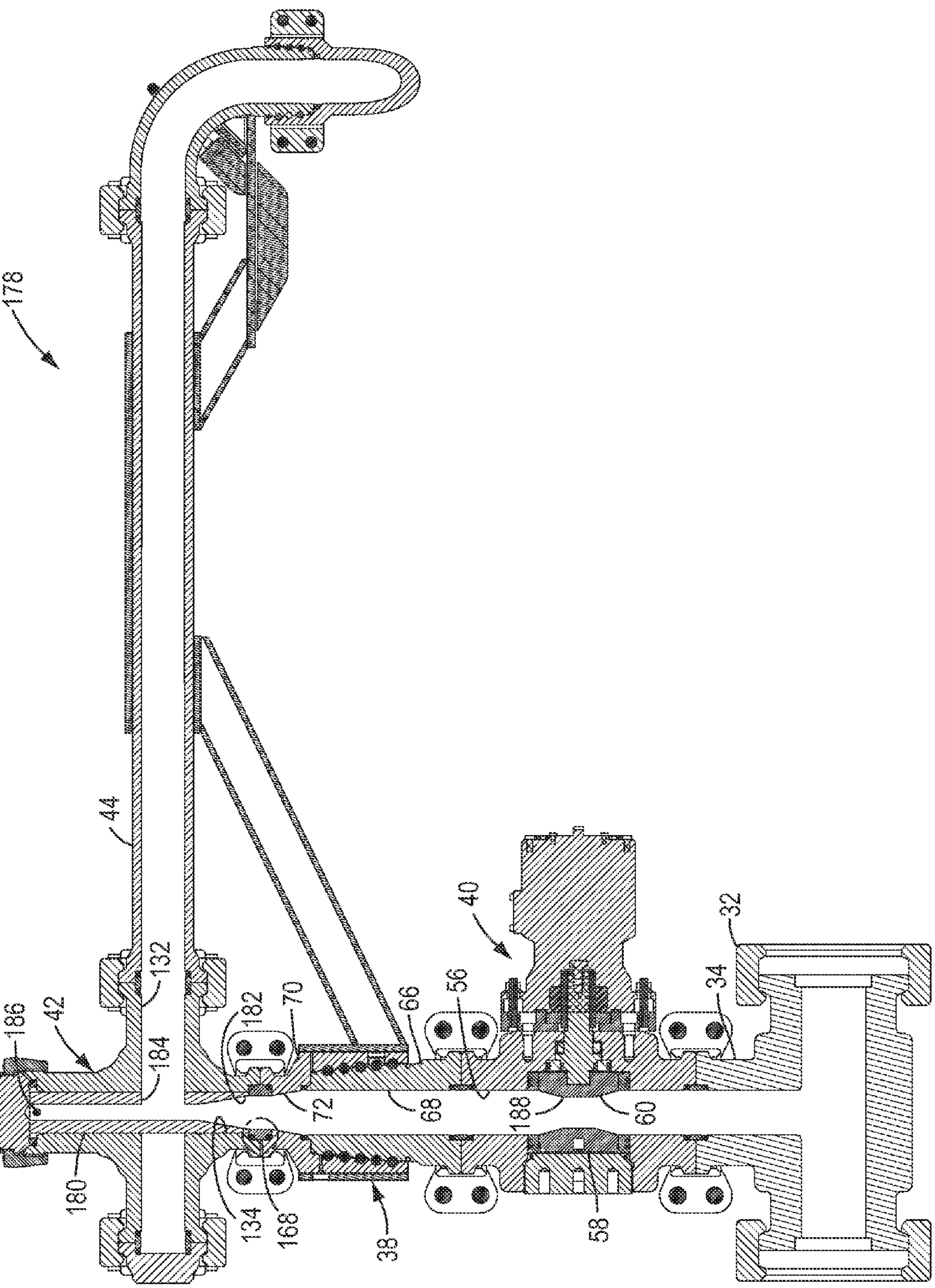
32
34
168
176
170
160
134
172
174
42
70

FIG. 7

FIG. 7A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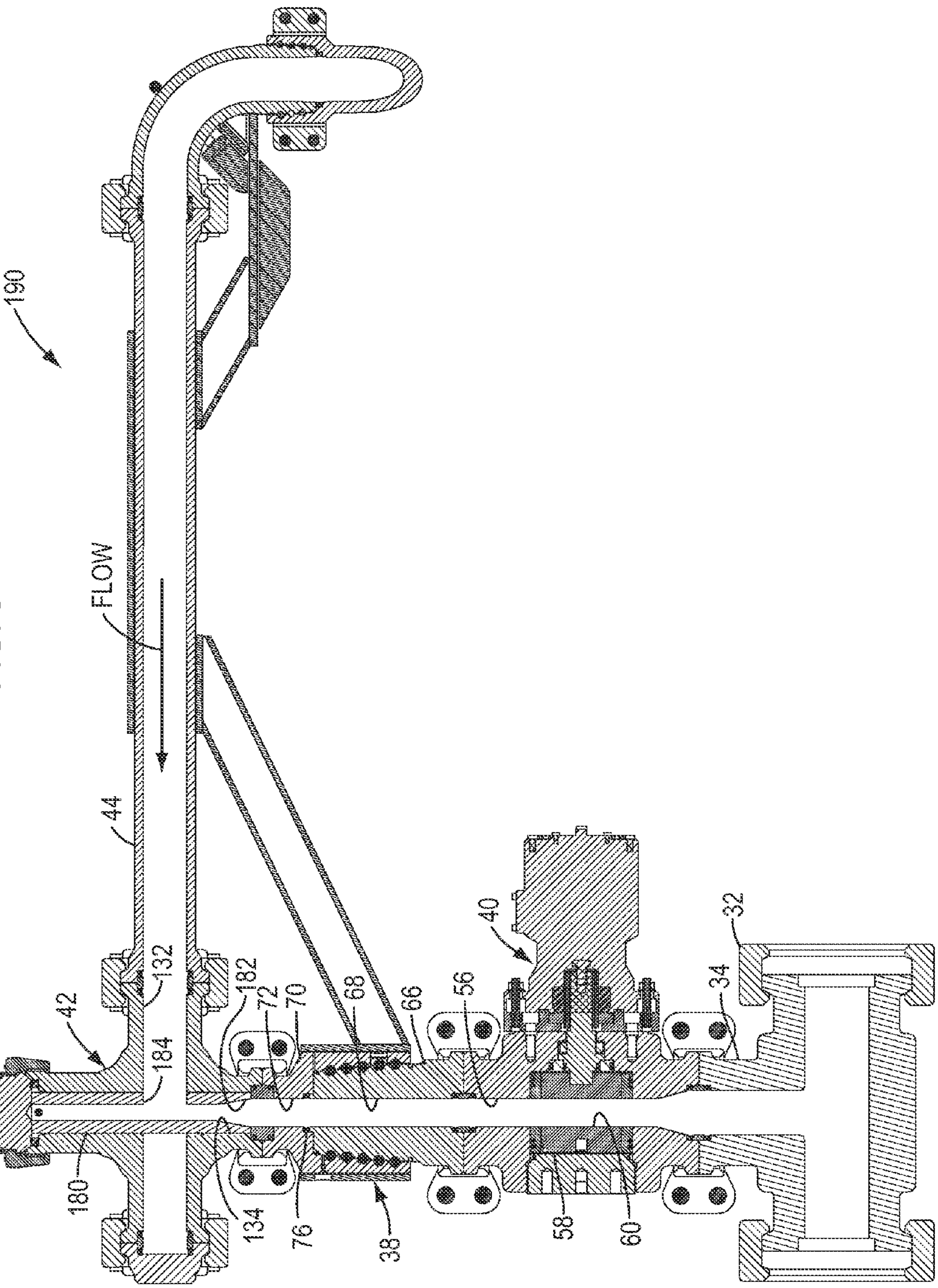
44
40
32
34
56
66
70
182
132
42
186
140
184
72
68
188
60
180
134
168
38
58

FIG. 8

FIG. 9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FLOW
44
42
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76
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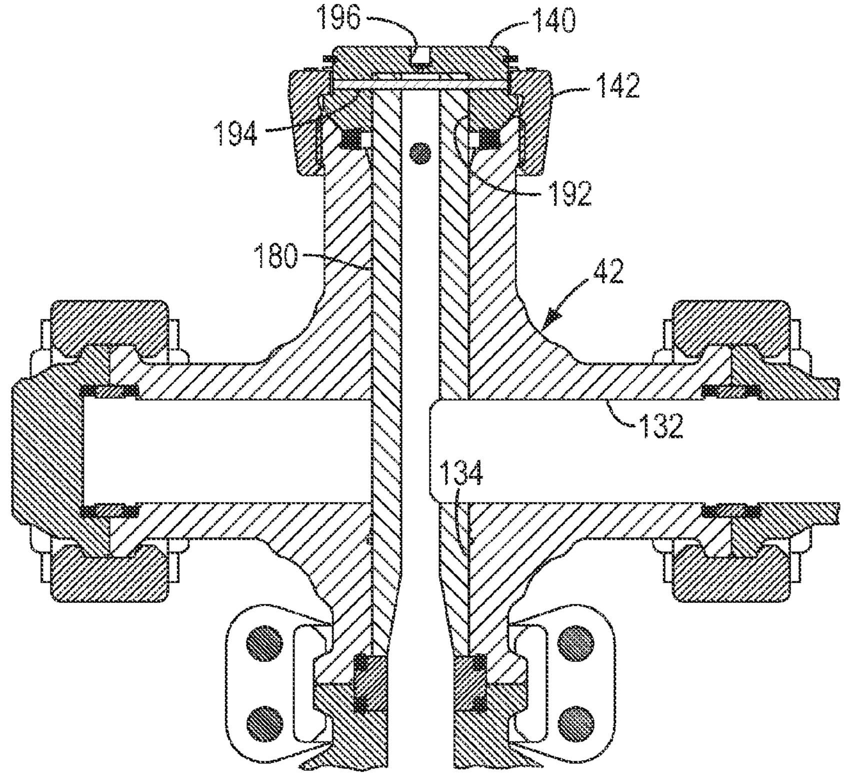
182
72
70
68
66
56
40
58
60
34
32

FIG. 10


196
140
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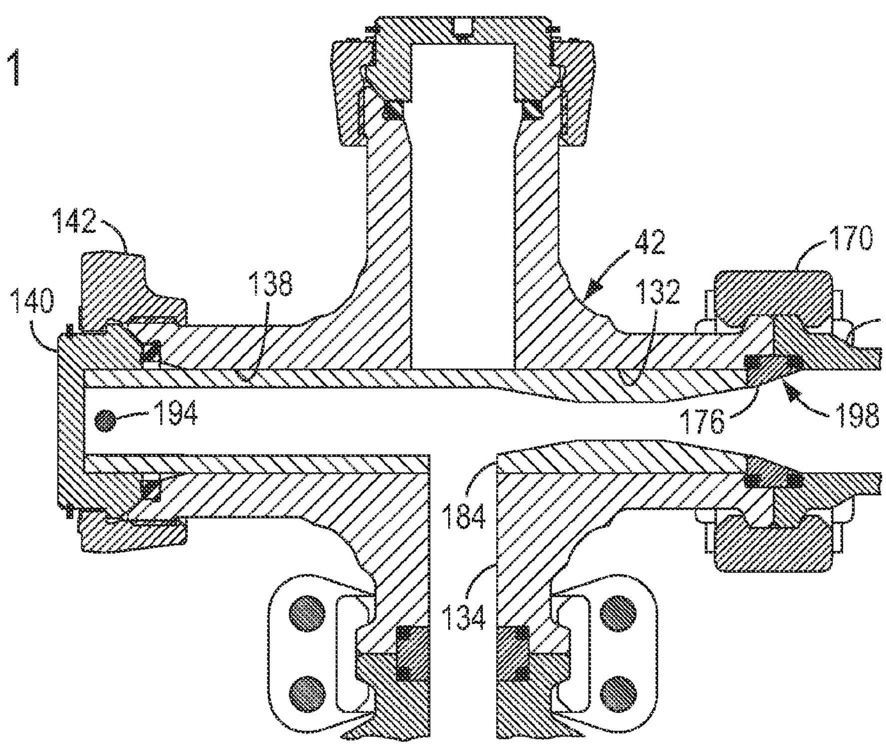
134

FIG. 11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184
134

FIG. 12

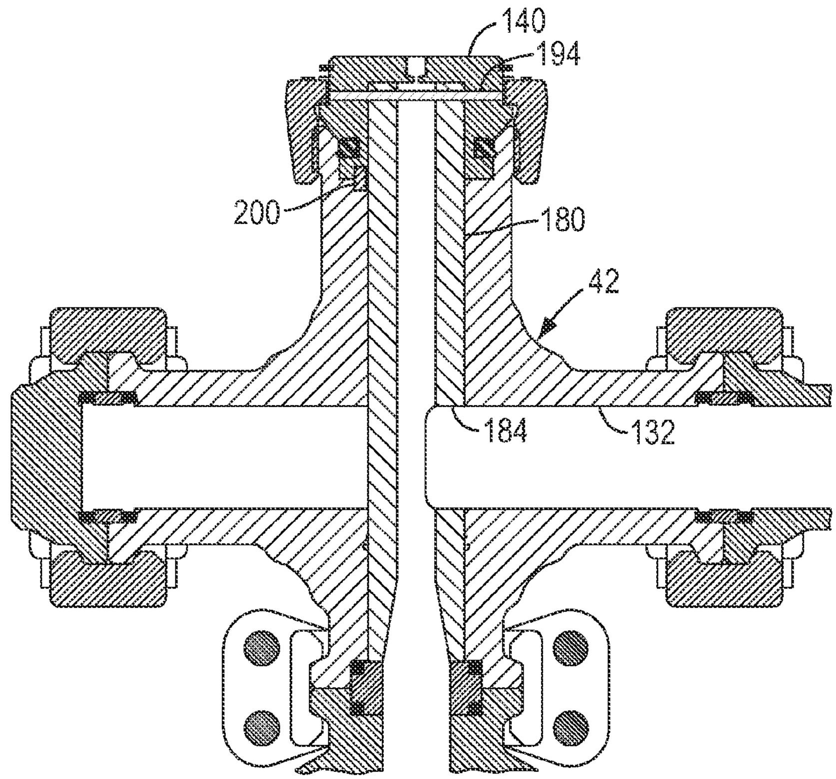



FIG. 13

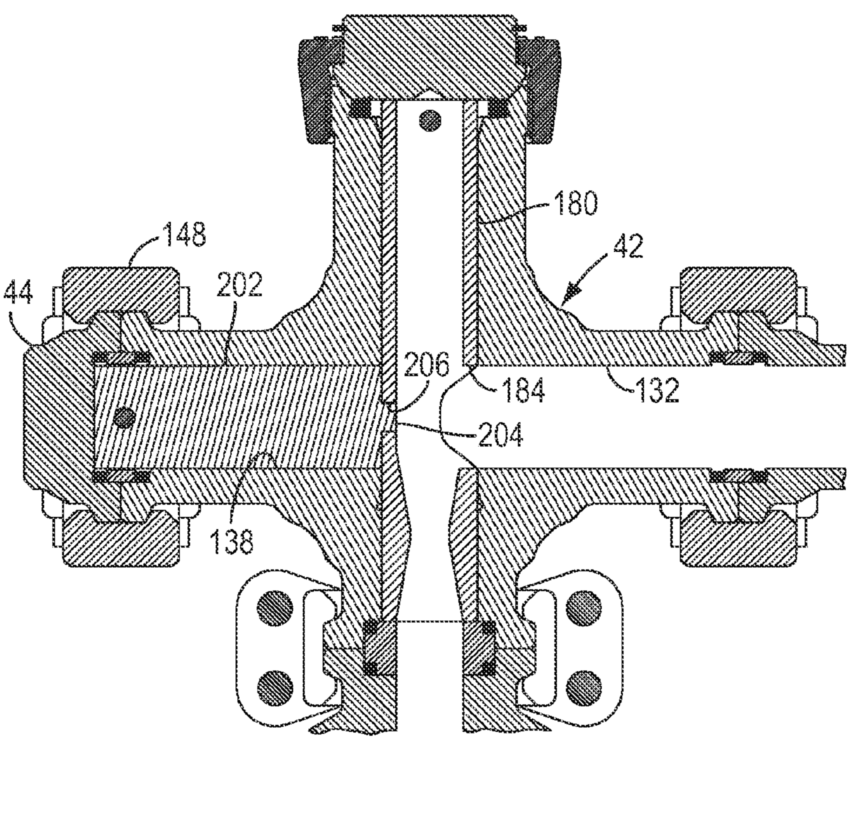
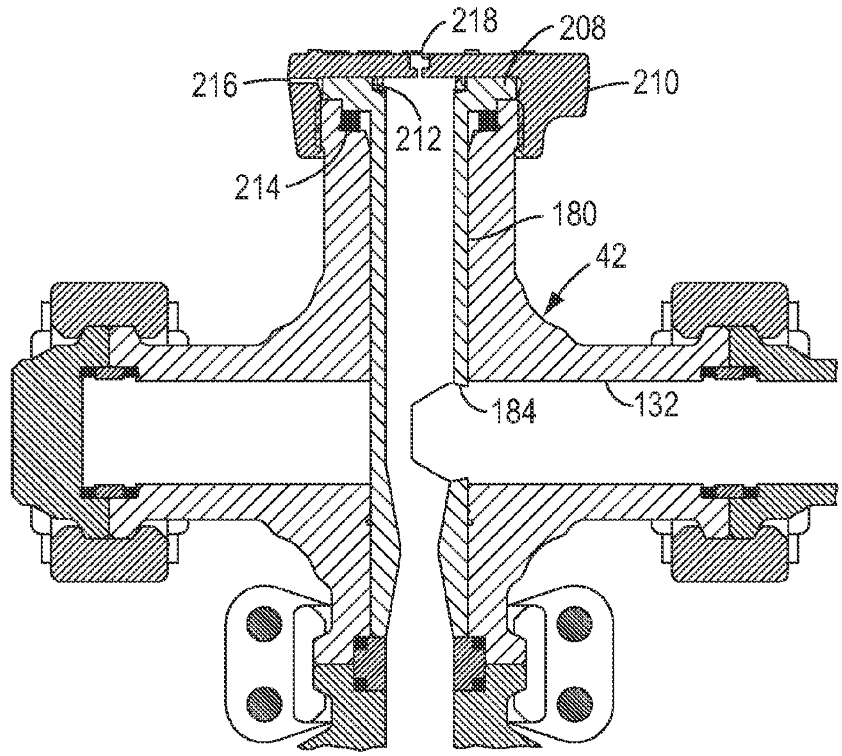
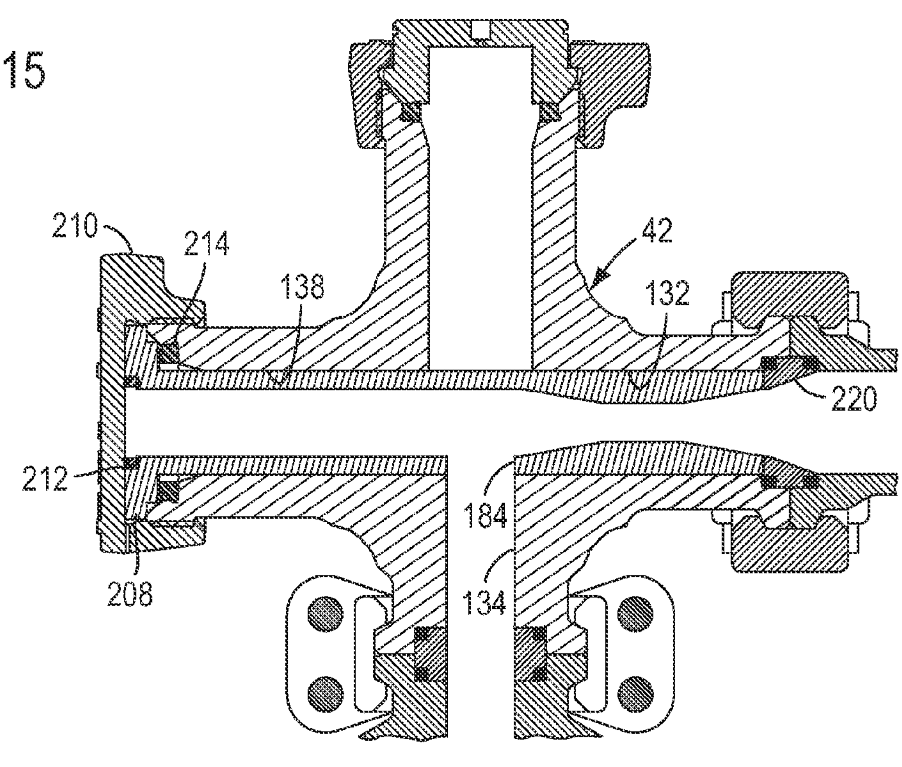


FIG. 14



218
208
216
210
212
214
180
42
184
132


FIG. 15



210
214
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220
212
184
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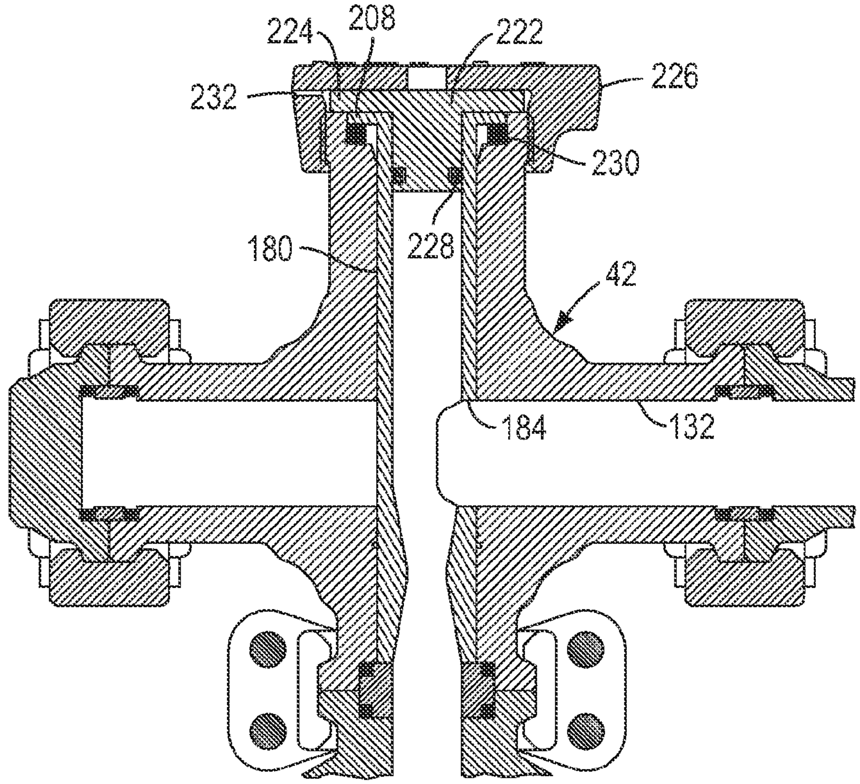
134

FIG. 16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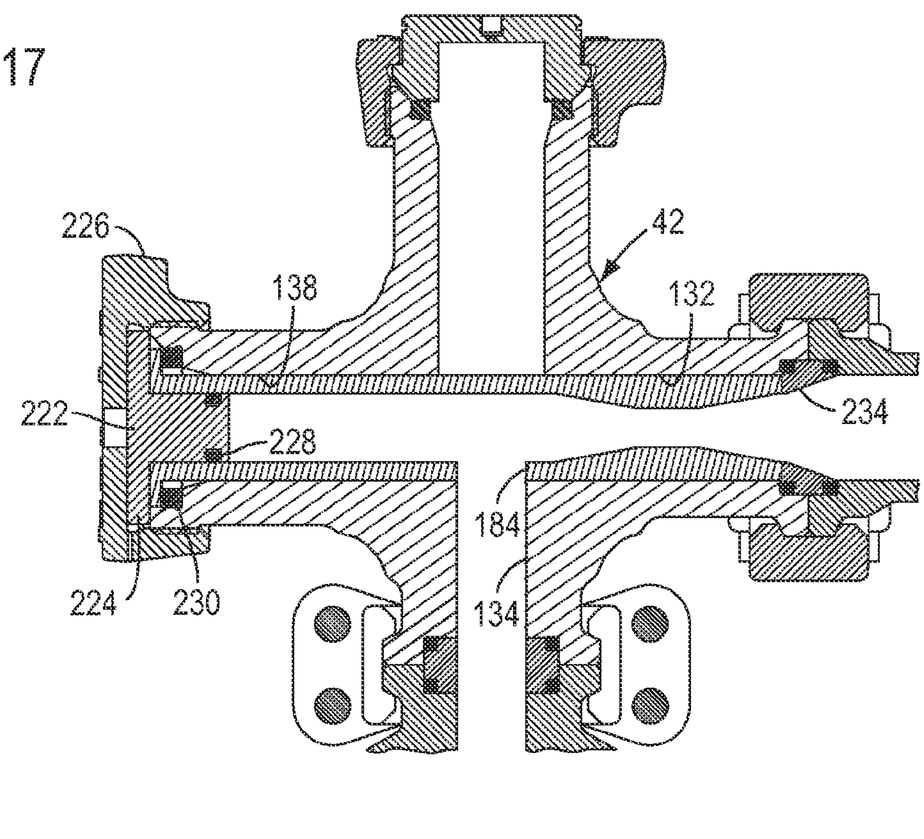
184
132

FIG. 17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184
224
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134

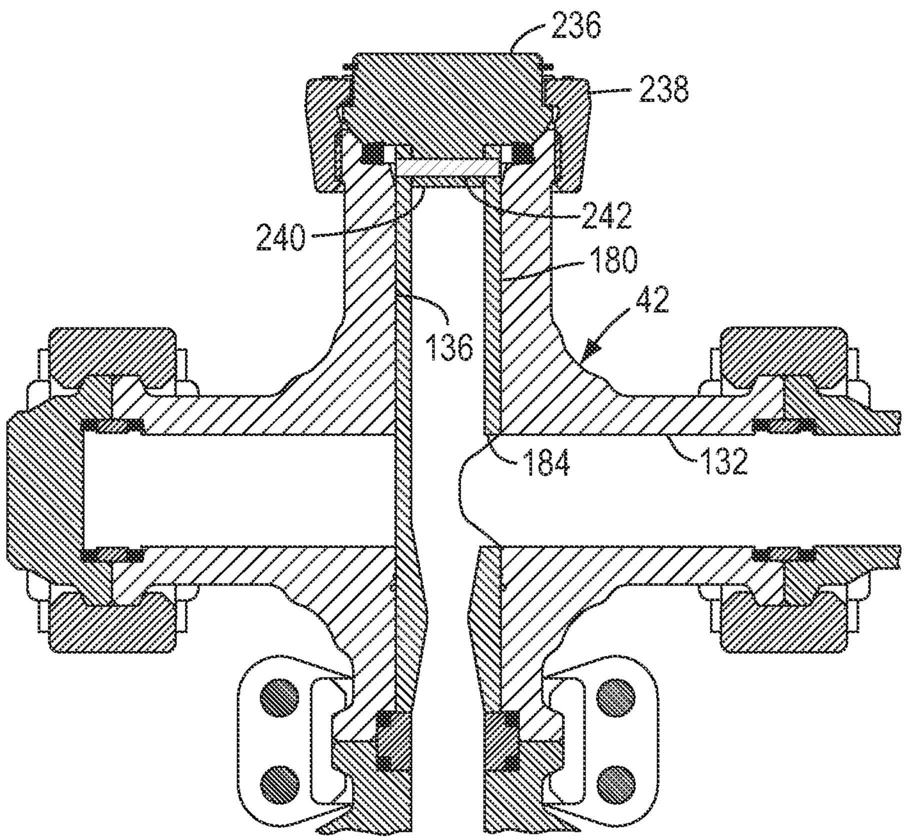


FIG. 18

## MANIFOLD ASSEMBLY WITH MULTIPLE ARTICULATING ARM ASSEMBLIES

This application is based on and claims priority from U.S. patent application Ser. No. 14/129,006 filed on Dec. 23, 2013, now U.S. Pat. No. 9,004,104, which in turn is based on and claims priority from International Patent Application No. PCT/US2011/001194 filed on Jul. 8, 2011.

### BACKGROUND OF THE INVENTION

The present invention is directed to a manifold assembly for connecting a plurality of pumping units to a main line which in turn is connectable to a wellhead or the like. More particularly, the invention is directed to a manifold assembly which comprises a plurality of articulating arm assemblies which are each connected to the main line and extendable for connection to respective pumping units.

High pressure well service pumping units are commonly used in the hydrocarbon production industry to inject a variety of fluids into an oil or gas well during certain well servicing operations. For example, during a fracturing operation such pumping units are used to inject a particle-containing slurry into the well in order to fracture the hydrocarbon bearing formation and thereby produce channels within the formation through which the oil or gas may flow.

Typical fracturing operations require the use of several pumping units operating in unison to inject a large volume of slurry into the well. The pumping units are mounted on respective trucks or trailers which are parked close together, and the discharge pipe assembly of each pumping unit is connected to the so called main line of a collection manifold which is located on a separate manifold trailer.

The connection between each pumping unit and the main line is usually made using a temporary flow line comprising a collection of individual and pre-assembled pipes and swivel joints which are secured together by clamps or connectors. The flow line components are stowed on the truck or trailer in compact configurations, and when the truck or trailer reaches the job site, they must be unfolded and assembled in order to extend the flow line to the main line. However, this operation is time consuming, especially when multiple pumping units must be connected to the main line.

Also, in order to provide adequate support for the flow line, a common practice is to run the flow line from the truck or trailer to the ground and then from the ground to the collection manifold. However, this requires that each flow line be made up of several swivel joints comprising multiple swivel connections. In addition, the parts of the flow line which rest on the ground can experience undue wear that may shorten the life of these components. Furthermore, the numerous components of the many flow lines create cramped and cluttered conditions in the area between the pumping units and the manifold trailer, which can be a safety hazard for persons assembling the flow lines.

Furthermore, each flow line is typically connected to choke in order to create a pressure drop in the fluid flowing through the flow line and reduce pressure pulsations in the main line resulting from operation of the pumping units. The choke usually includes a fixed orifice choke insert which is mounted in a choke housing. The choke housing is normally connected to an isolation valve which in turn is connected to the main line. Thus, if the choke insert needs to be replaced, the choke housing must usually be disconnected from both the flow line and the isolation valve. Also, creating a desired pressure drop over a single choke usually results in a large amount of erosion in the isolation valve.

### SUMMARY OF THE INVENTION

According to the present invention, these and other limitations in the prior art are addressed by providing a manifold assembly for connecting a plurality of pumping units to at least one wellhead. The manifold assembly comprises at least one main line which is connectable to the wellhead and includes a plurality of discharge connectors, and a plurality of articulating arm assemblies which are each connected to a corresponding discharge connector. Each arm assembly comprises a connector member which includes at least an inlet port, an outlet port and a third port that is located generally opposite the outlet port and is closed by a removable plug member; an articulating conduit assembly which comprises a first end that is connected to the inlet port and a second end that is connectable to a corresponding one of said plurality of pumping units; and a riser swivel which is connected between the outlet port and the discharge connector. In use of the manifold assembly each arm assembly is connected to a corresponding pumping unit and the main line is connected to the wellhead to thereby connect the pumping units to the wellhead.

The present invention will now be described with reference to the accompanying drawings. In the drawings, the same reference numbers may be used to denote similar components in the various embodiments.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a side elevation view of an illustrative embodiment of the manifold assembly of the present invention shown mounted on a truck trailer;

FIG. **1**B is a top plan view of the manifold assembly of FIG. **1**;

FIG. **2** is a perspective view of one embodiment of an articulating arm assembly which is suitable for use as part of the manifold assembly of FIG. **1**;

FIG. **3** is a cross sectional view of the articulating arm assembly of FIG. **2** shown mounted on a T connector;

FIG. **3**A is an enlarged cross sectional view of an embodiment of the seal assembly component of the articulating arm assembly of FIG. **3**;

FIG. **4** is a cross sectional view of an embodiment of a riser swivel seal arrangement which is suitable for use in the articulating arm assembly of FIG. **3**;

FIG. **5** is a cross sectional view of another embodiment of a riser swivel seal arrangement which is suitable for use in the articulating arm assembly of FIG. **3**;

FIG. **6** is a cross sectional view of a second embodiment of an articulating arm assembly which is suitable for use as part of the manifold assembly of FIG. **1**;

FIG. **7** is a cross sectional view of a third embodiment of an articulating arm assembly which is suitable for use as part of the manifold assembly of FIG. **1**;

FIG. **7**A is an enlarged cross sectional view of an embodiment of the seal assembly component of the articulating arm assembly of FIG. **7**;

FIG. **8** is a cross sectional view of another embodiment of an articulating arm assembly which is suitable for use as part of the manifold assembly of FIG. **1**;

FIG. **9** is a cross sectional view of yet another embodiment of an articulating arm assembly which is suitable for use as part of the manifold assembly of FIG. **1**; and

FIGS. **10-18** are cross sectional views of the cross connector component of the articulating arm assembly of the present invention showing alternative embodiments for mounting and orienting the choke insert component of the invention.

## DETAILED DESCRIPTION OF THE INVENTION

A manifold assembly in accordance with an illustrative embodiment of the present invention is shown in FIGS. **1**A and **1**B. The manifold assembly of this embodiment is shown mounted on an exemplary truck trailer and will accordingly be referred to hereafter as a manifold trailer. The manifold trailer, generally **10**, may be used in the oil and gas production industry to perform servicing operations on a well. For example, in a well fracturing operation the manifold trailer **10** may be used to inject a slurry into the wellbore in order to fracture the hydrocarbon bearing formation and thereby produce channels through which the oil or gas may flow. In this operation the manifold trailer **10** connects a slurry source to a number of high pressure pumping units and connects the high pressure pumping units to a wellhead mounted at the top of the wellbore. Thus, the manifold trailer eliminates the need to provide separate connections between the slurry source and each high pressure pumping unit and between each high pressure pumping unit and the wellhead.

As shown in FIGS. **1**A and **1**B, the manifold trailer **10** comprises a chassis **12** which is supported on a number of wheels **14** to allow the manifold trailer to be towed between various locations. An intake manifold assembly **16** is supported on the chassis **12** and includes one or more (e.g., two as shown in FIG. **1**B) longitudinally extending intake pipes **18** which are fluidly connected at their adjacent ends by transverse end pipes **20**. Each end pipe **20** includes a number of intake connectors **22** which are connectable to a slurry source, such as a blender or storage tank (not shown), by corresponding conduits (not shown). In addition, each intake pipe **18** includes a number of suction connectors **24** which are each connectable to the suction side of a corresponding high pressure pumping unit (not shown) by a respective conduit. Thus, the intake manifold assembly **16** connects the slurry source to each of the high pressure pumping units.

Referring still to FIGS. **1**A and **1**B, the manifold trailer **10** also includes one or more (e.g., two as shown in FIG. **1**B) longitudinally extending main pipes or lines **26**. One end of each main line **26** is closed by a cap or plug **28**, while the other end is provided with one or more injection connectors **30** which are each connectable to a corresponding wellhead (not show) by a respective conduit (not shown). Each main line **26** comprises a number of straight pipe sections and optional elbows (not shown) which are connected together by T connectors **32**. The branch of each T connector **32** defines a discharge connector **34** which is connectable to the discharge side of a corresponding high pressure pumping unit by means which will be described below. In the exemplary embodiment of the invention shown in FIG. **1**, each main line **26** comprises five T connectors **32** and thus five discharge connectors **34**. As a result, each main line **26** is capable of connecting up to five high pressure pumping units to a corresponding wellhead.

In accordance with the present invention, some or all of the discharge connectors **34** are connected to corresponding high pressure pumping units by respective articulating arm assemblies **36**. In the embodiment of the invention shown in FIGS. **1**A and **1**B, wherein each of the two main lines **26** is provided with five discharge connectors **34**, the manifold trailer **10** may comprise ten arm assemblies **36**, each of which connects an associated discharge connector to the discharge side of a corresponding high pressure pumping unit.

Referring to FIGS. **2** and **3**, each arm assembly **36** includes a riser swivel **38** which is connected to an isolation valve **40** that in turn is connected to the T connector **32**, a connector member, such as a four-port cross connector **42**, which is connected to the top of the riser swivel, and an articulating conduit assembly which is connected to the cross connector. The conduit assembly includes a generally horizontal inner arm **44** which is connected to the cross connector, a first swivel joint **46** which is connected to the distal end of the inner arm, an outer arm **48** which is connected to the distal end of the first swivel joint, a second swivel joint **50** which is connected to the distal end of the outer arm, and an end connector **52** which is connected to the distal end of the second swivel joint and is connectable to a pumping unit P.

As shown best in FIG. **3**, the isolation valve **40** may comprise a standard plug valve which includes a valve body **54** through which a valve bore **56** extends, a closure member in the form of a plug member **58** which includes a plug bore **60** that aligns with the valve bore when the isolation valve is in the open position, a rotatable stem **62** which is connected to the plug member, and an actuator **64** which is connected to the valve body over the stem. Alternatively, a handwheel or other manual actuation device (not shown) may be coupled to the stem instead of the actuator **64**. In operation, the actuator **64** rotates the stem **62** to thereby move the plug member **58** between the open position shown in FIG. **3** and a closed position in which the plug bore **60** is offset from the valve bore **56**. A suitable isolation valve **40** for use with the present invention is the Model 3 inch 15 k ULT plug valve made by FMC Technologies, Inc. of Houston, Tex.

Referring still to FIG. **3**, the riser swivel **38** comprises a male swivel part **66** through which a male swivel bore **68** extends and a female swivel part **70** through which a female swivel bore **72** extends. The male swivel part **66** is received in the female swivel part **70** and is rotatably connected thereto in a conventional fashion, such as with a plurality of balls **74**. At least one primary seal member **76** is positioned between the male swivel part **66** and the female swivel part **70** to thereby provide a continuous sealed flow path between the male swivel bore **68** and the female swivel bore **72**.

Referring also to FIG. **4**, the primary seal member **76**, which is shown positioned in an annular seal pocket **78** formed in the female swivel part **70**, may comprise a face type ring seal **80** having a generally rectangular or slightly trapezoidal cross section and an anti-extrusion ring **82** which is positioned in a corner of the ring seal. The ring seal **80** and anti-extrusion ring **82** may be made of any appropriate materials, such as nitrile elastomer and brass, respectively. An example of a primary seal member **76** which is suitable for use in the riser swivel **38** is the TripleStep Instream packing made by FMC Technologies, Inc.

Referring still to FIG. **4**, in addition to the first primary seal member **76**, the riser swivel **38** may be provided with a second primary seal member **84**. The second primary seal member **84**, which may be of the same construction as the first primary seal member **76**, is positioned between the male swivel part **66** and the female swivel part **70** downstream of the first primary seal member (where the term "downstream" is in reference to a potential leak path from the male and female swivel bores **68**, **72** to the exterior of the riser swivel **38**). As shown in FIG. **4**, the second primary seal member **84** may be disposed in an annular seal pocket **86** which is formed in the female swivel part **70**. Alternatively, the second primary seal member **84** may as shown in FIG. **5** be positioned in an annular seal pocket **86'** which is formed in the male swivel part **66**.

The second primary seal member **84** ideally comprises the same or a similar pressure rating as the first primary seal member **76**. Accordingly, the second primary seal member **84** will enable the riser swivel **38** to remain in service under normal operating conditions even if the first primary seal member **76** develops a leak. In this regard, the operator may monitor the sealing integrity of the first primary seal member **76** and, if a leak is detected, continue operating the arm assembly **36** until a leak is detected in the second primary seal member **84**. Thus, the use of the first primary seal **76** and the second primary seal **84** is superior to the use in the prior art of a primary seal and a secondary or backup seal since in the latter arrangement the secondary seal is normally designed to retain pressure only temporarily until the riser swivel can be removed from service if a leak is detected in the primary seal.

The sealing integrity of the first primary seal member **76** may be monitored through a first leak detection port **88** which extends to between the first and second primary seal members **76**, **84**. Likewise, the sealing integrity of the second primary seal member **84** may be monitored through a second leak detection port **90** which extends to between the second primary seal member **84** and the balls **74**. The second leak detection port **90** may also be used to inject a corrosion inhibitor onto the second primary seal member **84**. Also shown in FIG. **4** are a number of conventional swivel components, including a grease injection port **94** which is closed by a cap screw **96**, an upper grease seal **98**, a lower grease seal **100**, and a ball port **102**.

Referring again to FIG. **3**, the cross connector **42** may be connected to the inner arm **44** and the inner arm may be connected to the first swivel joint **46** by suitable first connectors **104**. Also, the first swivel joint **46** may be connected to the outer arm **48** and the outer arm may be connected to the second swivel joint **50** by suitable second connectors **106**. In addition, the cross connector **42** may be connected to the female swivel part **70** by a third connector **108**, the male swivel part **66** may be connected to the isolation valve **40** by a fourth connector **110**, and the isolation valve may be connected to the discharge connector **34** (which in this case is defined by the branch of the T connector **32**) by a fifth connector **112**. Each of the connectors **104** and **108**-**112** may comprise, for example, conventional clamp-type connectors, while the second connectors **106** may comprise, e.g., hammer unions.

Referring still to FIG. **3**, the inner arm **44** is sealed to the cross connector **42** by a first seal assembly **114**, the cross connector is sealed to the female swivel part **70** by a second seal assembly **116**, the male swivel part **66** is sealed to the isolation valve **40** by a third seal assembly **118**, and the isolation valve is sealed to the discharge connector **34** (i.e., the branch of the T connector **32**) by a fourth seal assembly **120**. In the embodiment of the invention shown in FIG. **3**, the seal assemblies at clamp locations **114**-**120** and **148** are identical. Therefore, these seal assemblies may be described with reference to FIG. **3**A, which is an enlarged view of the second seal assembly **116**. As shown in FIG. **3**A, the second seal assembly **116** comprises a bushing **122** which comprises a generally rectangular cross section, a first ring seal **124** which is positioned between the bushing and a recessed seal pocket **126** that is formed in the cross connector **42**, and a second ring seal **128** which is positioned between the bushing and a recessed seal pocket **130** that is formed in the female swivel part **70**. The first and second ring seals **124**, **128** may comprise face-type ring seals similar to the seal member **76** described above. The bushing **122** may be made of any suitable material, such as alloy steel.

Referring again to FIG. **3**, the cross connector **42** includes an inlet port **132** which is fluidly connected to the inner arm **44**, an outlet port **134** which is fluidly connected to the female swivel bore **72**, a top port **136** and a side port **138**. The top port **136** is closed by a top plug **140** which is secured to the cross connector **42** by, e.g., a wing union nut **142**. In accordance with the present invention, the top port **136** is located vertically above the inlet port **132**, the inner arm **44**, the first swivel joint **46**, the outer arm **48** and the second swivel joint **50**. As a result, the top port **136** provides the highest access point to the flow bore extending through the arm assembly **36**. Thus, when the arm assembly **136** is being pressurized, for example during hydrostatic pressure tests, the top plug **140** can be opened to bleed off any air which may be trapped in the arm assembly. In addition, the top port **136** provides access for installation of a choke insert in the outlet port **134** without having to disconnect the cross connector **42** from either the inner arm **44** or the riser swivel **38**.

The side port **138** is closed by a side plug **144** which is secured to the cross connector **42** by, e.g., a clamp-type connector **146** and is sealed to the cross connector by a side port seal assembly **148**. In accordance with the present invention, the side port **138** may function as, e.g., an inspection port, a pump priming port, an access for a horizontal choke insert and/or a flow cushioning chamber.

Also, in one embodiment of the invention the cross connector **42** is ideally configured so that the same or similar connectors may be used for the connectors **104**, **146** and the same or similar seal assemblies may be used for the seal assemblies **114**, **148**. This will enable the cross connector **42** to be oriented such that either the inlet port **132** or the side port **138** is connected to the inner arm **44**. In this manner, in the event the inlet port **132** reaches its erosion limit, the cross connector **42** can be re-installed with the side port **138** connected to the inner arm **44** to thereby substantially extend the life of the cross connector.

A second embodiment of the arm assembly of the present invention is shown in FIG. **6**. The arm assembly of this embodiment, generally **150**, is similar in many respects to the arm assembly **36** described above. Therefore, only those features of the arm assembly **150** which are different from those of the arm assembly **36** will be described.

As shown in FIG. **6**, the arm assembly **150** comprises a fixed orifice choke insert **152** which is positioned in a counterbore **154** formed in the outlet port **134** of the cross connector **42** and comprises a choke orifice **156** that communicates with the inlet opening **132**. The choke insert **152** may be retained in position in the counterbore **154** by any suitable means, such as a snap ring **158** which is received in a corresponding groove formed in the counterbore above the choke insert. The choke insert **152** may be removed and replaced through the top port **136** of the cross connector **42** by simply removing the top plug **140**. Therefore, the cross connector **42** does not need to be disconnected from the riser swivel **38** and/or the inner arm **44** in order to replace the choke insert **152**.

As is known in the art, the choke insert **152** acts to reduce the pressure of the fluid flowing through the arm assembly **150** and to dampen pressure pulsations in the main line **26**. However, effecting a desired pressure drop over a single choke insert **152** may result in a high degree of erosion in portions of the arm assembly **150** located downstream of the choke insert.

In accordance with the present invention, the riser swivel **38** is configured to produce an additional pressure drop downstream of the choke insert **152**. As a result of this arrangement, a larger orifice choke insert **152** may be used and the erosion caused by a large pressure drop over a single choke may accordingly be decreased. As shown in FIG. **6**, the riser swivel **38** is configured to produce the second pressure drop by reducing the diameter of the female swivel bore **72** and then gradually increasing the diameter of the male swivel bore **68** until it is approximately the same as the diameter of the plug bore **56**. For example, the diameter of the female swivel bore **72** may be approximately equal to the diameter of the choke orifice **156** at the exit end of the choke insert **152**, the diameter of the upstream end of the male swivel bore **68** may be approximately equal to the diameter of the female swivel bore, the diameter of the downstream end of the male swivel bore may be approximately equal to the diameter of the valve bore **56**, and the diameter of the male swivel bore may increase generally linearly from its upstream end to its downstream end. In this manner, the desired pressure drop will occur over the choke insert **152** and the male swivel bore **68**.

A third embodiment of the arm assembly of the present invention is shown in FIG. **7**. The arm assembly of this embodiment, generally **160**, comprises a fixed orifice choke insert **162** which is positioned in the outlet port **134** of the cross connector **42** and includes a choke orifice **164** which communicates with the inlet port **132** via a number of inlet openings **166**. The choke insert **162** extends to approximately the top of the top port **136** and is therefore easily accessible by simply removing the plug **140**.

In this embodiment, the choke insert **162** supported on a seal assembly **168** which is positioned between the cross connector **42** and the female swivel part **70** and is retained in position by the plug **140**. Referring to FIG. **7**A, the seal assembly **168** is similar to the seal assembly **116** described above in that it comprises a bushing **170**, a first ring seal **172** which is engaged between the cross connector **42** and the bushing, and a second ring seal **174** which is engaged between the female swivel part **70** and the bushing. The first and second ring seals **172**, **174** may be similar to the ring seals **124**, **128** of the seal assembly **116**, and the bushing **170** may be made of the same material as the bushing **122**. In this embodiment, however, the bushing **170** comprises a preferably integral support ring **176** which projects radially into the outlet port **134** and thereby provides a support for the bottom of the choke insert **162**.

As in the previous embodiment, the riser swivel **38** is configured to produce a second pressure drop in the fluid flowing through the arm assembly **160**. As shown in FIG. **7**, the riser swivel **38** is so configured by reducing the diameter of the upstream end of the female swivel bore **72** and then gradually increasing the diameter of the female swivel bore until the diameter of the downstream end of the female swivel bore is approximately the same as the diameter of the male swivel bore **68**. For example, the diameter of the upstream end of the female swivel bore **72** may be approximately equal to the diameter of the choke orifice **164** at the exit end of the choke insert **162**, the diameter of the downstream end of the female swivel bore **72** may be approximately equal to the diameter of the male swivel bore **68**, and the diameter of the female swivel bore may increase generally linearly from its upstream end to its downstream end. In this manner, the desired pressure drop through the arm assembly **160** will occur over the choke insert **162** and the female swivel bore **72**.

A fourth embodiment of the arm assembly of the present invention is shown in FIG. **8**. The arm assembly of this embodiment, generally **178**, comprises a fixed orifice choke insert **180** which is positioned in the outlet port **134** of the cross connector **42** and includes a choke orifice **182** that communicates with the inlet opening **132** via a single inlet opening **184**. The choke insert **180** extends to approximately the top of the top port **136** and includes a pull bar **186** which extends transversely across an upper end portion of the choke insert to facilitate removal and orientation of the choke insert.

In the embodiment of the invention shown in FIG. **8**, the female swivel bore **72** is configured as described above in connection with FIG. **7** in order to produce a second pressure drop in the fluid flowing through the arm assembly **178**. In addition, the isolation valve **140** is configured to produce a third pressure drop by modifying the plug bore **60** to include a plug orifice **188**. The plug orifice **188** comprises a diameter smaller than the diameter of the valve bore **56**. In a preferred embodiment of the invention, the plug orifice **188** comprises a diameter approximately equal to the diameter of the choke orifice **182** at the exit end of the choke insert **180**. Thus, the desired pressure drop through the arm assembly **178** will occur over the choke insert **180**, the female swivel bore **72** and the plug member **58**. Moreover, the pressure drop across the plug member **58** will reduce the erosion rate of the plug member.

Another embodiment of the arm assembly of the present invention is shown in FIG. **9**. The arm assembly of this embodiment, generally **190**, is similar to the arm assembly **178** discussed above. However, in this embodiment the plug bore **60**, the portion of the valve bore **56** located above the plug member **58**, the male swivel bore **68** and the female swivel bore **72** ideally all comprise approximately the same diameter as the choke orifice **182** at the exit end of the choke insert **180**. This allows the use of a smaller primary seal member **76** for the riser swivel **38**, which in turn reduces the hydrostatic force acting between the male swivel part **66** and the female swivel part **70**. In addition, the second pressure drop across the arm assembly **190** is produced by increasing the diameter of the portion of the valve bore **56** located below the plug member **58** to match the diameter of the T connector **32**.

Several alternative features for the above-described embodiments will now be described with reference to FIGS. **10-18**.

In the embodiment shown in FIG. **10** the upper end of the choke insert **180** is received in a recess **192** which is formed in the plug **140** and is secured thereto with a transverse pin **194**. Thus, the choke insert **180** may be removed from the cross connector **42** by simply disconnecting the wing union nut **142** and removing the plug **140**. The plug **140** may also be provided with a pressure test port **196**.

In the embodiment shown in FIG. **11**, the choke insert **180** is positioned in the inlet port **132** of the cross connector with the side opening **184** in alignment with the outlet port **134**. The top or left end (as viewed in FIG. **11**) of the choke insert **180** extends through the side port **138** and, as with the FIG. **10** embodiment, is received in the recess **192** and secured to the plug **140** with the pin **194**. In this embodiment, the bottom or right end of the choke insert **180** is retained by a seal assembly **198** which is positioned between the inner arm **44** and the cross connector **42**. The seal assembly **198**, which is similar to the seal assembly **168** described above, includes a bushing **170** having a support ring **176** which is engaged by the bottom or right end of the choke insert **180**.

The embodiment shown in FIG. **12** is similar to that shown in FIG. **10**. However, in the FIG. **12** embodiment a locator pin **200** is provided to aid in orienting the choke insert **180** relative to the cross connector **42**. In particular, the top of the locator pin **200** is received in a corresponding hole in the plug **140** and, when the side opening **184** is aligned with the inlet port **132**, the bottom end of the locator pin is received in a corresponding hole in the cross connector **42**.

FIG. **13** illustrates another means for orienting the choke insert **180** relative to the inlet port **132** of the cross connector **42**. In this embodiment a locator pin **202** comprising a small diameter axial projection **204** is positioned in the side port **138** of the cross connector **42**. When the side opening **184** is properly oriented with the inlet port **132**, the projection **204** is received in a corresponding hole **206** in the choke insert **180**. As with the embodiment shown in FIG. **3**, the side port **138** is closed by a plug **144** which is sealed to the cross connector with a seal assembly **148**.

In the embodiment shown in FIG. **14**, the choke insert **180** comprises an upper flange which is trapped between a blind wing union nut **210** and an adjacent portion of the cross connector **42**. An upper seal **212** is positioned between the upper flange **208** and the wing union nut **210** and a lower seal **214** is positioned between the upper flange and the cross connector **42**. The upper and lower seals **212**, **214** may be similar to the seal member **76** described above. In addition, the wing union nut **210** may comprise a vent port **216** to release trapped pressure and a pressure test port **218**.

The embodiment shown in FIG. **15** is similar to that shown in FIG. **14**. However, in this embodiment the choke insert **180** is positioned in the inlet port **132** with the side opening **184** in alignment with the outlet port **134** and the flange **208** positioned at the opening of the side port **138**. In addition, the bottom or right end of the choke insert **180** is retained by a seal assembly **220** similar to the seal assembly **198** described above in connection with FIG. **11**.

In the embodiment shown in FIG. **16**, a blind plug **222** is provided which extends into the top of the choke insert **180**. The blind plug **222** includes a rim **224** which is secured against both the flange **208** of the choke insert **180** and an adjacent portion of the cross connector **42** by a blind wing union nut **226**. An inner seal **228** is positioned between the blind plug **222** and the choke insert **228** and an outer seal **230** is positioned between the choke insert and the cross connector **42**. The inner and outer seals **228**, **230** may be similar to the seal member **76** described above. In addition, and the wing union nut **226** may include a vent port **232** to release trapped pressure.

The embodiment shown in FIG. **17** is similar to that shown in FIG. **16**; however, in this embodiment the choke insert **180** is positioned in the inlet port **132** with the side opening **184** in alignment with the outlet port **134** and the blind plug **222** positioned at the opening of the side port **138**. In addition, the bottom or right end of the choke insert **180** is retained by a seal assembly **234** similar to the seal assembly **198** described above in connection with FIG. **11**.

In the embodiment shown in FIG. **18**, the top port **136** is closed by a plug **236** which is secured to the cross connector **42** by a wing union nut **238**. The plug **236** includes a reduced diameter bottom portion **240** which is received in the top of the choke insert **180** and is secured thereto with a pin **242**.

The manifold trailer **10** may be provided with means for supporting the arm assemblies **36** on the chassis **12**. Referring again to FIGS. **1**A and **1**B, for example, each lateral pair of arm assemblies **36** is supported on the chassis **12** with a corresponding brace member **244**. Each brace member **244** includes a support **246** which is connected to the chassis **12** (or another component which in turn is connected to the chassis) by suitable means, such as welding, and a transverse cross bar **248** which is connected to the top of the support. Each end of the cross bar **248** is connected to a corresponding arm assembly **36** with, for example, a collar **250** that is bolted to either the female swivel part **70** or the portion of the cross connector **42** through which the top port **136** extends. In addition, a beam member **252** may be connected to successive cross bars **248** in order to provide longitudinal stability to the brace members **244**.

Thus, it may be seen that the arm assemblies **36** are connected to and supported by the manifold trailer **10** at all times. Consequently, separate conduit assemblies are not required to be transported from location to location independently of the manifold trailer **10**. In addition, when setting up for well servicing operations, separate conduit assemblies do not need to be connected between the high pressure pumping units and the main lines **26**. Instead, with the manifold trailer **10** of the present invention the main lines **26** can be connected to the high pressure pumping units by simply extending the outer arm **48** of each arm assembly **36** to a corresponding pumping unit.

Each arm assembly **36** may comprise means for supporting the inner arm **44** in a generally horizontal position and for reducing the bending and torsional loads acting on the connector **104** between the inner arm and the first swivel joint **46**. Referring to FIGS. **2** and **3**, for example, each arm assembly **36** may comprise a diagonal brace **254** which extends between a collar **256** that is bolted or otherwise connected to the female swivel part **70** and a sleeve **258** that is bolted or otherwise connected to the inner arm **44**. At least the upper half of the sleeve **258** extends along the inner arm **44** and is coupled to the first swivel joint **46** with a generally V-shaped bracket **260**. The bracket **260** includes a first end **262** which is bolted or otherwise connected to the sleeve **258** and a second end **264** which is secured with a U bolt **266** or other suitable means to the upper elbow **268** of the swivel joint **46**. The second end **264** comprises a diagonal first plate **270** which includes a semi-circular cutout that engages the underside of approximately the middle of the elbow **268** and a horizontal second plate **272** which includes a semi-circular cutout that engages the distal end portion of the elbow. Thus, the brace **254** supports the inner arm **44** in a generally horizontal position, while the bracket **260**, and in particular the engagement of the first and second plates **270**, **272** with the elbow **266**, transfers the bending and torsional loads acting on the first swivel joint **46** to the inner arm **44**, thereby preventing these loads from acting on the connector **104**, which could otherwise cause the connector to become loose.

Each arm assembly **36** may also include means for counterbalancing the weight of the outer arm **48** as it is being deployed. Referring to FIG. **2**, for example, each arm assembly **36** may include a counterbalance hydraulic cylinder **274** which is secured between the first swivel joint **46** and the outer arm **48**. The cylinder **274** has a first end which is rotatably connected to a bridge plate **276** that is clamped or otherwise connected to the outer arm **48**. The second end of the cylinder **274** is rotatably connected to a generally horizontally-extending bracket **278** that is clamped or otherwise connected to the horizontal swivel part **280** of the first swivel joint **46**. The bracket **278** may be supported by a vertical plate **282** which is connected to the middle elbow **284** of the first swivel joint **46** with a U bolt **286** or other suitable means. The cylinder **274** may comprise a simple fluid filled or spring cylinder. Alternatively, cylinder **274** may comprise a hydraulic cylinder whose pressure is controlled to provide a constant counterbalance force to the outer arm **48**.

It should be recognized that, while the present invention has been described in relation to the preferred embodiments thereof, those skilled in the art may develop a wide variation of structural and operational details without departing from the principles of the invention. For example, the various elements shown in the different embodiments may be combined in a manner not illustrated above. Therefore, the appended claims are to be construed to cover all equivalents falling within the true scope and spirit of the invention.

What is claimed is:

**1**. A manifold assembly for connecting a plurality of pumping units to at least one wellhead, the manifold assembly comprising:

at least one main line which is connectable to the wellhead, said main line including a plurality of discharge connectors;

a plurality of articulating arm assemblies which are each connected to a corresponding discharge connector, each arm assembly comprising:

a connector member which includes at least an inlet port, an outlet port and a third port that is located generally opposite the outlet port and is closed by a removable plug member;

an articulating conduit assembly which comprises a first end that is connected to the inlet port and a second end that is connectable to a corresponding one of said plurality of pumping units; and

a riser swivel which is connected between the outlet port and the discharge connector;

whereby in use of the manifold assembly each arm assembly is connected to a corresponding pumping unit and the main line is connected to a wellhead to thereby connect the pumping units to the wellhead.

**2**. The manifold assembly of claim **1**, wherein the third port is positioned vertically above the inlet and outlet ports.

**3**. The manifold assembly of claim **2**, wherein the manifold assembly is configured such that the third port is positioned vertically above the conduit assembly when the second end is connected to the pumping unit.

**4**. The manifold assembly of claim **2**, further comprising a choke insert which is positioned in the outlet port and is removable through the third port.

**5**. The manifold assembly of claim **4**, wherein the choke insert is supported on a seal assembly which is positioned between the connector member and the riser swivel.

**6**. The manifold assembly of claim **4**, wherein the choke insert extends through the third port to the plug member.

**7**. The manifold assembly of claim **6**, wherein the choke insert is connected to the plug member.

**8**. The manifold assembly of claim **4**, wherein the choke insert includes at least one inlet opening and the arm assembly further comprises means for aligning the inlet opening with the inlet port.

**9**. The manifold assembly of claim **4**, wherein the plug member comprises a blind nut and the choke insert comprises a radial flange which is trapped between the blind nut and an adjacent portion of the connector member to thereby secure the choke insert within the connector member.

**10**. The manifold assembly of claim **1**, wherein the connector member comprises a fourth port which is located generally opposite the inlet port and is closed by a second removable plug member.

**11**. The manifold assembly of claim **10**, wherein the connector member is configured such that each of the inlet port and the fourth port is connectable to the conduit assembly.

**12**. The manifold assembly of claim **11**, further comprising a choke insert which is positioned in the inlet port and is removable through the fourth port.

**13**. The manifold assembly of claim **12**, wherein the choke insert is positioned against a seal assembly which is positioned between the connector member and the conduit assembly.

**14**. The manifold assembly of claim **12**, wherein the choke insert extends through the fourth port to the second plug member.

**15**. The manifold assembly of claim **14**, wherein the choke insert is connected to the second plug member.

**16**. The manifold assembly of claim **4**, wherein:

the choke insert includes a choke orifice which comprises an exit opening diameter at an end of the choke orifice adjacent the riser swivel;

the riser swivel includes a male swivel part which comprises a male swivel bore and a female swivel part which comprises a female swivel bore; and

the diameter of at least one of the male swivel bore and the female swivel bore increases from a first diameter approximately equal to the exit opening diameter to a second, larger diameter to thereby create a pressure drop in a fluid flowing through the riser swivel.

**17**. The manifold assembly of claim **4**, wherein:

the choke insert includes a choke orifice which comprises an exit opening diameter at an end of the choke orifice adjacent the riser swivel;

the riser swivel includes a male swivel part which comprises a male swivel bore and a female swivel part which comprises a female swivel bore;

the female swivel part is located adjacent the choke insert;

the diameter of the female swivel bore increases from a first diameter approximately equal to the exit opening diameter to a second, larger diameter; and

the diameter of the male swivel bore is approximately equal to the second diameter.

**18**. The manifold assembly of claim **4**, wherein:

the choke insert includes a choke orifice which comprises an exit opening diameter at an end of the choke orifice adjacent the riser swivel;

the riser swivel includes a male swivel part which comprises a male swivel bore and a female swivel part which comprises a female swivel bore;

the female swivel part is located adjacent the choke insert;

the diameter of the female swivel bore is approximately equal to the exit opening diameter; and

the diameter of the male swivel bore increases from a first diameter approximately equal to the exit opening diameter to a second, larger diameter.

**19**. The manifold assembly of claim **4**, wherein the riser swivel is connected to an isolation valve which in turn is connected to the discharge connector.

**20**. The manifold assembly of claim **19**, wherein:

the choke insert includes a choke orifice which comprises an exit opening diameter at an end of the choke orifice adjacent the riser swivel;

the riser swivel includes a male swivel part which comprises a male swivel bore and a female swivel part which comprises a female swivel bore;

the diameter of the male swivel bore is approximately equal to the exit opening diameter;

the diameter of the female swivel bore is approximately equal to the exit opening diameter; and

the isolation valve includes a valve bore which comprises a diameter that increases from a first diameter approximately equal to the exit opening diameter to a second, larger diameter.

**21**. The manifold assembly of claim **19**, wherein:

the choke insert includes a choke orifice which comprises an exit opening diameter at an end of the choke orifice adjacent the riser swivel;

the isolation valve includes a valve bore and a closure member which is positioned across the valve bore;

the valve bore comprises a diameter which is larger than the exit opening diameter; and

the closure member includes a closure member bore which comprises an orifice having a diameter which is approximately equal to the exit opening diameter.

**22**. A manifold assembly for connecting a plurality of pumping units to at least one wellhead, the manifold assembly comprising:

at least one main line which is connectable to the wellhead, said main line including a plurality of discharge connectors;

a plurality of articulating arm assemblies which are each connected to a corresponding discharge connector, each arm assembly comprising:

a connector member which includes at least an inlet port, an outlet port and a third port that is located generally opposite the inlet port and is closed by a removable plug member;

an articulating conduit assembly which comprises a first end that is connected to the inlet port and a second end that is connectable to a corresponding one of said plurality of pumping units; and

a riser swivel which is connected between the outlet port and the discharge connector;

whereby in use of the manifold assembly each arm assembly is connected to a corresponding pumping unit and the main line is connected to a wellhead to thereby connect the pumping units to the wellhead.

**23**. The manifold assembly of claim **22**, wherein the connector member is configured such that each of the inlet port and the third port is connectable to the conduit assembly.

**24**. The manifold assembly of claim **22**, further comprising a choke insert which is positioned in the inlet port and is removable through the third port.

**25**. The manifold assembly of claim **24**, wherein the choke insert is positioned against a seal assembly which is positioned between the connector member and the conduit assembly.

**26**. The manifold assembly of claim **24**, wherein the choke insert extends through the third port to the plug member.

**27**. The manifold assembly of claim **26**, wherein the choke insert is connected to the plug member.

**28**. The manifold assembly of claim **24**, wherein the choke insert includes at least one inlet opening and the arm assembly further comprises means for aligning the inlet opening with the outlet port.

**29**. The manifold assembly of claim **24**, wherein the plug member comprises a blind nut and the choke insert comprises a radial flange which is trapped between the blind nut and an adjacent portion of the connector member to thereby secure the choke insert within the connector member.

**30**. A manifold assembly for connecting a plurality of pumping units to at least one wellhead, the manifold assembly comprising:

at least one main line which is connectable to the wellhead, said main line including a plurality of discharge connectors;

a plurality of articulating arm assemblies which are each connected to a corresponding discharge connector, each arm assembly comprising:



a connector member which includes at least an inlet port and an outlet port;

an articulating conduit assembly which comprises a first end that is connected to the inlet port and a second end that is connectable to a corresponding one of said plurality of pumping units; and

a riser swivel which is connected between the outlet port and the discharge connector;

wherein each arm assembly defines a flow bore extending between the connector member and the discharge connector; and

wherein said flow bore comprises a bore section having a diameter which increases from a first diameter to a second, larger diameter in a direction toward the discharge connector to thereby create a pressure drop in a fluid flowing through the flow bore;

whereby in use of the manifold assembly each arm assembly is connected to a corresponding pumping unit and the main line is connected to a wellhead to thereby connect the pumping units to the wellhead.

**31**. The manifold assembly of claim **30**, wherein:

the riser swivel includes a male swivel part which comprises a male swivel bore and a female swivel part which comprises a female swivel bore; and

at least one of the male swivel bore and the female swivel bore comprises said bore section.

**32**. The manifold assembly of claim **30**, wherein:

the riser swivel is connected to an isolation valve which in turn is connected to the discharge connector; and

the isolation valve includes a valve bore which comprises said bore section.

**33**. The manifold assembly of claim **32**, wherein the riser swivel includes a male swivel part having a male swivel bore and a female swivel part having a female swivel bore, and wherein at least one of the male swivel bore and the female swivel bore comprises a diameter which is approximately equal to the first diameter.

**34**. The manifold assembly of claim **30**, wherein:

the riser swivel is connected to an isolation valve which in turn is connected to the discharge connector;

the isolation valve includes a valve bore and a closure member which is positioned across the valve bore; and

the closure member includes a closure member bore which comprises said bore section.

**35**. The manifold assembly of claim **34**, wherein the riser swivel includes a male swivel part having a male swivel bore and a female swivel part having a female swivel bore, and wherein at least one of the male swivel bore and the female swivel bore comprises a diameter which is approximately equal to the first diameter.

**36**. The manifold assembly of claim **35**, wherein at least one of the male swivel bore and the female swivel bore comprises a second bore section having a diameter which increases in a direction toward the discharge connector to thereby create a pressure drop in a fluid flowing through the flow bore.

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